AN EVALUATION OF DEPARTMENT OF DEFENSE CONTRACTORS' COST PERFORMANCE

THESIS

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Master of Science in Cost Analysis

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Preface

The purpose of this study was to investigate contractor performance and determine whether specific actions led to recovery from cost overruns. Additionally, the study investigated contracts from 49 contractors to determine whether a statistical difference existed in contractor cost or schedule performance.

We would like to thank our thesis advisor, Dr. David Christensen, for his guidance and patience in completing this study. We would also like to thank Dr. Richard Antolini for his effort in helping us making contacts to gather crucial information. Most importantly, we would like to thank our spouses, Karen and Jeff, for their support and understanding through all the long nights and weekends.

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Abstract

This study examines the cause of cost overrun recoveries within Department of Defense (DoD) contracts. In this time of extremely limited congressional funding, it is crucial the DoD avoid cost overruns. Information provided to contracting officers and contractors which would help avoid cost overruns would prove extremely valuable to the DoD. This study attempts to address this problem in two ways: 1) Determine the cause of overrun recoveries; 2) determine whether a statistical difference in cost and schedule performance exists among DoD contractors.

Interviews, document reviews, and a two-sample t-test were used to analyze the contracts that recovered from early cost overruns. One-Way Analysis of Variance, along with normality tests and equality-of-variance tests were used to analyze the contractors' cost and schedule performance.

The specific contract reviewed for contract recovery actions revealed no specific management action that led to the recovery. Additionally, more than 300 contracts across 49 contractors revealed no significant statistical

difference between contractors in the areas of cost and schedule performance.

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I. Introduction

Management Issue

The Department of Defense (DoD) solicits bids for development and procurement of major weapon systems. Companies compete for the contracts by submitting proposals for the project. On the basis of these proposals, the DoD awards the contract and expects the contractor to deliver the product without exceeding the budget for the weapon system.

Unfortunately, the military services have suffered serious setbacks in the development of new weapon systems due to uncontrollable cost overruns. Ideally, a contractor should recover from an early cost overrun (complete a project on or under budget despite experiencing a cost overrun early in the contract); however, the majority of contractors have been unable to recover from these overruns. The DoD would like to break the existing pattern and help contractors deliver weapon systems without exceeding the specified budget for the system.

In addition, a contractor's cost performance history should weigh heavily in the award of a contract. However, information pertaining to a contractor's past performance has received little attention in the source selection process (11:18168). An analysis of DoD contractors' past performance will provide beneficial information to government source selection teams.

Specific Problem

The Department of Defense expects contractors to recover from cost overruns. However, very few contractors have successfully recovered from cost overruns experienced beyond the 15 percent completion point in the contract (1).

Additionally, the Federal Government is taking steps to incorporate past performance of government contractors in the source selection process (11:18168). To determine the usefulness of this information, the statistical difference between contractors' cost performance should be tested. If no statistical difference exists, the selection of a contractor can be made without regard to past contractor performance.

Investigative Questions

1. In the past, have any contractors recovered from early cost overruns?

    a. Did the recovery from the cost overruns occur because of specific action taken by the contractor?

    b. What action did the contractor take to recover from the cost overrun?

2. Do commonalities exist between contractors that have successfully recovered from cost overruns?

3. Is there a significant statistical difference in the cost performance of DoD contractors?

4. Is there a significant statistical difference in the schedule performance of DoD contractors?

Scope/Limitations

The database used in this study is the 1991 version of the Defense Acquisition Executive Summary (DAES) provided by the Office of the Under Secretary of Defense for Acquisition [OUSD(A)] in Washington DC. Our study did not include any contracts outside of the DAES database. Contractors not submitting Contract Performance Reports (CPR) in the early and latter stages of the contract do not provide an adequate representation of contract performance. Additionally, it was necessary to compare contractor performance at several contract completion points. Therefore, consideration was limited to contracts that submitted CPRs before the 20% and after the 85% complete point.

For purposes of analyzing contract recoveries, the study was further limited to contracts which recovered from at least a 5% cost overrun when the contract was more than 15% complete. This limitation was imposed to eliminate insignificant recoveries where no specific action would have been necessary to recover from the cost overrun. In this situation, the initial overrun and eventual recovery could have been due to the "Earned Value" allocation methods or accounting practices utilized by the contractor.

Beneficial information as to the causes of recovery from a cost overrun could be obtained from determining the causes of the cost overrun itself. However, due to time constraints, no attempt was made to determine the causes of contract cost overruns.

The following chapter provides a summary of the current literature in the area of cost overruns. Chapter Three details the methodology used in the research, while Chapter Four presents the results of the analysis. The final chapter provides conclusions and recommendations for further research.

II. Literature Review

In looking at the causes and impacts of cost overruns, one must first understand the environment in which these overruns occur. In an attempt to control contract costs within the volatile acquisition environment, the government implemented several contract management systems (21:2).

Beginning in 1967, the DoD implemented a policy requiring defense contractors to comply with Cost/Schedule Control Systems Criteria (C/SCSC) to ensure effective control of contract performance and the provision of timely, accurate, and verifiable contract data to the government (3:2). While not a system, C/SCSC define 35 standards which, when followed, ensure contractors employ sound management practices (4:2). These criteria are mandatory for DoD Research and Development contracts in excess of $60 million and production contracts in excess of $250 million (7:11B2).

DoD 5000.2M mandates contractors required to comply with C/SCSC report cost and schedule performance periodically in the form of a Contract Performance Report (CPR) to evaluate current contract status (4:14). Those contracts exempt from C/SCSC compliance with a value exceeding $5 million and duration greater than 12 months are typically required to submit cost and schedule performance information via Cost/Schedule Status Report (7:20-8).

Another important component in assessing contractor performance is the Performance Measurement Baseline (PMB). The PMB represents the Budgeted Cost of Work Scheduled (BCWS) at every point throughout the life of the contract. It is the baseline against which contractor cost and schedule performance is measured.

Several studies have been conducted in the area of C/SCSC. These studies have primarily focused on two areas: (1) Estimate at Completion (EAC), the most current estimate of final contract cost based upon contractor performance to date; and (2) the inadequacies of current DoD cost control measures. There is a discernible absence of research in the area of contractor recoveries from cost overruns.

In order to determine the factors leading to recoveries, the probable causes of cost overruns must first be identified. The causes of cost overruns can be separated into two categories, those within the control of program managers and those outside their control. The most severe and prevalent causes of cost overruns fall into the latter category.

It is generally accepted that the primary cause of most overruns is unrealistic PMBs (12:10), a problem partially outside the control of program managers. Several factors contribute to unrealistic PMBs. Contractors typically negotiate unachievable contract costs to secure contract award hoping future funding adjustments will alleviate the inevitable overruns (12:7). Once awarded the contract, the contractor must either frontload the baseline or allocate unrealistic budgets to every work package. In reality, the contractor is merely prolonging inevitable budget problems (12:7).

Overly optimistic government cost estimates, caused by competition for limited funding, also lead to unachievable PMBs (10:146). In a 1986 study, the GAO found that over 90% of government contracts were awarded for amounts less than the government's own estimates (10:168). In 1979, the director of the Procurement and Systems Acquisition Division of the General Accounting Office (GAO) stated "The planning estimates (sent through the DoD and on to Congress) are not honest. I think they are highly optimistic for a specific purpose, and that is to get the program started." (10:146)

Significant technical problems and funding delays are additional causes of obsolete baselines (12:6). Technical problems on a contract require additional time, resources, and effort to resolve. This additional effort disrupts the normal contract flow and forces increased contract cost(12:6). Funding delays inevitably cause a stretching of the contract schedule (12:7). Stretching the schedule adds additional cost to the contract and deems the original baseline obsolete (12:7).

A second cause of overruns beyond the control of program managers is the insistence by end-item users for more exotic technology in weapon systems (20:152). Contractors avoid identifying unrealistic specifications in fear of being eliminated from further consideration for contract award (10:147). In addition, contractors must submit excessively low bids to guarantee contract award, resulting in underfunded contracts to meet desired specifications (10:147).

Program managers exhibit little control over their program in that a large number of staff people can insist that the program comply with a myriad of special requirements without regard for performance or price (13:49). Program managers typically include these special requirements, intending to secure the funding source at a later time (10:147).

There are a limited number of causes of cost overruns which the program manager can directly impact. Perhaps the most damaging of these causes is the failure to heed early warning signs of cost/schedule problems. The cancellation of the Navy's A-12 program is prime example of the catastrophic consequences which can result from the failure to take action (2). Since history shows overruns identified later in the program are less likely to cause adverse congressional action and more likely to receive corrective funding, program managers are reluctant to identify problems early (13:52).

An additional cause of cost overruns is a lack of technological expertise by the program office staff (13:51). This lack of knowledge hinders program managers' ability to identify unreasonably optimistic performance goals established by contractors (13:51). The AH-56A Cheyenne Attack Helicopter offers a documented case where the prime contractor defined unrealistic performance goals which went unchallenged by naive Army officials, resulting in cancellation of the program due to exorbitant cost increases and technical problems (13:51).

The lack of documented research in the area of cost overrun recoveries provides the opportunity to contribute essential information. The goal of this research is to reduce dollars lost to cost overruns by providing contract managers with proven procedures for recovering from these overruns.

III. Methodology

Explanation of Method

The purpose of this research is to determine the cause of contract recoveries from cost overruns and to analyze the cost performance of DoD contractors. This chapter outlines the methods of analysis used to conduct the research. The research encompassed two main areas: (1) the analysis of successful contract recoveries; and (2) the analysis of DoD contractors' cost performance.

The Database

The population of interest is all DoD acquisition contracts. The data for the study was taken from the Defense Acquisition Executive Summary (DAES) database provided by the Office of the Under Secretary of Defense for Acquisition [OUSD(A)]. The DAES database contains cost performance data for 899 completed or near-completed acquisition contracts covering the period June 1970 to October 1992. It is a collection of Cost Performance Reports (CPR) submitted monthly/quarterly by contractors to outline cost and schedule performance. The contracts in the DAES database cover a wide range of military products, contract types, contract phases, and DoD components.

The Sample

Initially, the DAES database was pared down to eliminate those contracts exhibiting an Over Target Baseline (OTB) condition. When an OTB exists, the cost variance is no longer accurately represented in the CPR. Therefore, it was necessary to eliminate all OTB contracts to ensure the contracts in the sample contained accurate cost variances.

The sample was further reduced by eliminating all contracts which did not meet the following two criteria: (1) CPRs must have been submitted by the 20% completion point; and (2) CPRs must have been submitted at or beyond the 85% completion point. This step was necessary to ensure an accurate picture of the contracts' performances was available for the full life of the contracts. The step was also necessary to allow for analysis of cost performance at various stages of contract completion.

The reductions described above resulted in a reduced database of 303 contracts covering 49 contractors which met the basic criteria. This reduced database constituted the sample of interest for the research effort. These contracts were coded to allow publication of the results without revealing contractor identities. The code used is a dual number system with the first number signifying the contractor and the second number signifying the contract.

For example, Contract 25.8 represents the eighth contract in the database for Contractor #25. Since the sample is of sufficient size to adequately represent the population, it is assumed the results of this study can be generalized across all DoD contracts.

Contract Recoveries

A contract recovery occurs when a project is completed on or under budget despite experiencing a cost overrun early in the contract. The steps presented in the flow chart below were necessary to reduce the sample to those contracts which recovered from early cost overruns.

DECISION RULES
FOR
SELECTING "SUCCESSFUL" CONTRACTS

1. Calculate cost variances throughout contract.
2. Eliminate contracts not experiencing an overrun.
3. Eliminate contracts not recovering from the overrun.
4. Eliminate contracts with an insignificant recovery.
5. Eliminate contracts not representative of the population.

Figure 1. Decision Rules for Selecting "Successful" Contracts

Step 1: First, it was necessary to calculate the cost variance (CV) throughout the life of the contract. The CV throughout the contract life was calculated by subtracting the Actual Cost of Work Performed ($ACWP$) from the Budgeted Cost of Work Performed ($BCWP$) for each CPR.

$$CV = BCWP - ACWP \tag{1}$$

To calculate the CV at contract completion, it was necessary to first calculate the final ACWP ($ACWP_f$). Final ACWP was calculated using extrapolation from the latest CPR for the contract. The ACWP was divided by the percent complete (PC) reported on the contract's final CPR.

$$PC = \frac{BCWP}{BAC} \tag{2}$$

$$ACWP_f = \frac{ACWP}{PC} \tag{3}$$

Final CV (CV_f) was then computed by subtracting final ACWP from the final Budget at Completion (BAC_f). The final BAC is the BAC reported on the final CPR. The final BAC reported has been adjusted for all engineering change orders and other contract modifications.

$$CV_f = BAC_f - ACWP_f \tag{4}$$

Step 2: To determine those contracts which recovered from early cost overruns, each contract in the sample was examined for an overrun beyond the 15% complete point.

Step 3: Those contracts with overruns were further examined to determine whether a recovery was made by contract completion. Of the 303 contracts in the sample, only 30 contracts recovered from early cost overruns.

Step 4: The 30 "successful" contracts were reduced further by eliminating all contracts which did not experience a negative cost variance of at least five percent beyond the 15% complete point of the contract. This step eliminated contracts which may have recovered simply by chance from accounting practices or "earned value" allocation methods. This reduction of the sample left nine contracts which recovered from at least a five percent overrun beyond the 15% completion point.

Step 5: Of the nine successful contracts, Contract 37.11 was a construction contract and deemed not representative of the population. Therefore, this contract was eliminated from further analysis. This elimination left eight contracts for further study.

In an effort to determine the cause of the recoveries, the eight contracts which recovered from early cost overruns were examined in terms of: (1) DoD component (Army, Navy, Air Force); (2) Contract Type (Fixed Price or Cost Plus); (3) Contract Size (in $); (4) Most Unfavorable Schedule Variance Percentage ($SV_u\%$); (5) Stability of the Performance Measurement Baseline (PMB); and (6) Use of Management Reserve (MR). This examination was made in an effort to find similarities between the contracts that successfully recovered.

To determine $SV_u\%$, the schedule variance percentage ($SV\%$) was calculated for each CPR of the successful contracts. With SV% calculated throughout the life of the eight successful contracts, $SV_u\%$ was obtained for each contract. The schedule variance (SV) and schedule variance percentage were calculated as follows:

$$SV = BCWP - BCWS \tag{5}$$

$$SV\% = \frac{SV}{BCWS} \tag{6}$$

To further investigate the causes of contract recoveries, a comparison of mean cost variance percentages was conducted between the group of contracts recovering from cost overruns ($\overline{CV_R\%}$) and the remainder of the database

($\overline{CV_S\%}$). This comparison was conducted at the 25, 50, 75, and 100 percent complete points (first, second, third, and fourth quartile) of the contracts. Since the DAES database did not contain CPRs at exactly 25, 50, 75, and 100 percent complete, linear interpolation was used to calculate the cost variances at these milestones. This procedure provided usable results with negligible error.

$$\overline{CV_R\%} = \frac{\sum_{i=1}^{n_R} CV_{(R,i)}\%}{n_R} \tag{7}$$

Where:

i = an index for all contracts which recovered from an early cost overrun

n_R = the number of contracts which recovered from early cost overruns

$$\overline{CV_S\%} = \frac{\sum_{j=1}^{n_S} CV_{(S,j)}\%}{n_S} \tag{8}$$

Where:

j = an index for all contracts in the remainder of the database

n_S = the number of contracts in the remainder of the database

A two sample t-test, using Satterthwaite's approximation for the degrees of freedom, was used for the comparison of mean cost variance percentages. This test allows for an accurate comparison of means without requiring equal variances among the groups (18:96).

A prerequisite for using the t-test is normality of the data. However, the t-test is robust in the presence of mild departures from normality (8:343) To test for normality, a Rankit plot was produced and the Wilk-Shapiro statistic was computed. The hypotheses for the two-sample t-test were as follows:

$$H_o: \overline{CV_R\%} = \overline{CV_S\%}$$
$$H_a: \overline{CV_R\%} \neq \overline{CV_S\%}$$

test statistic (t'_{calc}) = $$\frac{\overline{CV_R\%} - \overline{CV_S\%}}{\sqrt{\frac{s_R^2}{n_R} + \frac{s_S^2}{n_S}}}$$

Where:

$\overline{CV_R\%}$ = the mean cost variance percentage of those contracts recovering from early cost overruns

$\overline{CV_S\%}$ = the mean cost variance percentage of the remainder of the database

s_R^2 = the sample variance of the recovered contracts

s_S^2 = the sample variance of the remainder of the database

n_R = the number of contracts recovering from an early cost overrun

n_S = the number of contracts in the remainder of the database

Satterthwaite's approximation for degrees of freedom in t'_{calc} is calculated as follows:

$$v' = \frac{(\upsilon_R + \upsilon_S)^2}{\frac{\upsilon_R^{\,2}}{v_R} + \frac{\upsilon_S^{\,2}}{v_S}}$$

Where:

$$v_R = n_R - 1$$

$$v_S = n_S - 1$$

$\upsilon_R = \frac{s_R^{\,2}}{n_R}$ with v_R degrees of freedom

$\upsilon_S = \frac{s_S^{\,2}}{n_S}$ with v_S degrees of freedom

Note: v' is then rounded down to the nearest integer to use the t-table

critical value (t_{crit}) = value from table of cumulative probabilities of student's t distribution (two-tailed test)

When $|t'_{calc}| > t_{crit}$, H_o is rejected indicating the mean cost variance percentages of the recovered contracts and the remainder of the database are not equal at the 95%

confidence level. This hypothesis test was conducted at the 25, 50, 75, and 100 percent complete points of the contracts. The Statistix 4.0 computer program was used to conduct this test (19). The results of the hypothesis test are discussed in Chapter Four.

The objective of the Wilk-Shapiro test is to evaluate the normality of a sample (17:602). The Wilk-Shapiro statistic is an effective measure of normality even for small samples (n<20) (17:602). The SAS computer program was used to calculate the Wilk-Shapiro statistic for the 25, 50, 75, and 100% complete points of the contracts. The Wilk-Shapiro statistic, along with the Rankit plots, provides an accurate measure of the normality of the samples.

The final step in analyzing contracts recovering from cost overruns involved selecting one contract for more in-depth analysis. Due to its product type, contract size, magnitude of recovery, and breadth of contractor's previous experience, Contract 37.4 was selected as the contract to be analyzed further.

To conduct the analysis, a supplementary form to the Cost Performance Report (CPR) was reviewed for each reporting period of the contract. This form provided cost and schedule data, as well as narrative explanations of cost and schedule variances. These reports were reviewed extensively to capture relevant contract information.

Firstly, the information in the DAES database was compared for accuracy to the actual supplementary forms obtained from the managing System Program Office. Secondly, the supplementary forms covering the periods in which the contract was experiencing negative cost variances were reviewed in detail in an effort to determine the factors which caused the overrun. Finally, the supplementary forms covering the periods in which the contractor was recovering from the cost overruns were reviewed extensively. The narrative of the CPRs was studied to determine whether any specific management action was identified by the contractor as leading to the overrun or recovery.

This final review was conducted in an effort to determine the specific management action which led to the recovery. The effort was focused on identifying those events, as detailed earlier in the literature review, which management had control over from those events which occurred regardless of management action. Events such as accounting errors and overestimation of overhead rates led to early cost overruns. Avoiding these events, which are within the control of the program office, would reduce the cost overruns experienced at the program office.

Contractor Performance

The sample of 303 contracts was divided by contractor, resulting in 49 separate groups. This separation was accomplished by ordering the contracts in the database alphabetically by contractor. The next step involved grouping each contractor's contracts to obtain a database arranged by contractor.

In an effort to compare contractor cost performance, a mean cost variance percentage ($\overline{CV\%}$) for each contractor was computed at the 25, 50, 75, and 100 percent complete points (first, second, third, and fourth quartiles) of the contracts. The $\overline{CV\%}$ was computed by averaging the cost variance percentages for all contracts administered by the contractor. The following formula was used to compute the mean cost variance percentage for each contractor ($\overline{CV_K\%}$):

$$\overline{CV_K\%} = \frac{\sum_{i=1}^{n_K} CV_{(K,i)}\%}{n_K} \tag{9}$$

Where:

K = the contractor number

i = an index representing a specific contract

n_K = the number of contracts for contractor K

To compare contractor performance, a comparison of mean cost variance percentages was conducted. The One-Way Analysis of Variance (ANOVA) option in Statistix Analytical Software (19:121) was used to conduct this comparison of means. In order to use One-Way ANOVA, the following two criteria must be met: (1) within group variances must be equal for all groups; and (2) each group's CV%s must be normally distributed (15:529).

Bartlett's test for equality of variances between the groups was conducted to determine whether the variances were equal. It should be noted that the F-test for equality of means with the fixed ANOVA model is only slightly affected when error variances are unequal (15:624).

The test for normality is important for use of the ANOVA model. However, the fixed ANOVA model is robust against small departures from normality (15:623). Rankit plots of all contracts in the sample were used at each quartile to test for normality among contractor mean CV%s. Additionally, Wilk-Shapiro statistics were computed to provide a quantitative test for normality.

As a further analysis of the difference between contractors, mean schedule variance percentages were investigated. Initially, the most unfavorable schedule variance percentage ($SV_u\%$) for each contract was determined via an automated search. This information was used to calculate each contractor's mean, most unfavorable schedule variance percentage ($\overline{SV_u\%}$). As with the comparison of cost variance percentages, One-Way ANOVA was used to compare mean, most unfavorable schedule variance percentages between contractors.

The tests for comparison of means were conducted using a microcomputer based statistical package called Statistix Analytical Software (19). A confidence level of 0.95 was used for all hypothesis tests. Cost and schedule variance calculations were accomplished in an Excel spreadsheet (14). A SAS computer program was used to calculate the Wilk-Shapiro statistics for normality of the samples (9).

This concludes the description of the methodology. The next chapter presents the analysis of contract recoveries as well as the comparison of contractors' cost and schedule performance.

IV. Analysis

Analysis of Contract Recoveries

The sample of 303 contracts was analyzed using the procedures outlined in the previous chapter to determine those contracts exhibiting a recovery from an early cost overrun. Of the 303 contracts in the sample, only eight (2.64%) successfully recovered from an early cost overrun. These eight contracts are summarized in Table 1.

TABLE 1

SUMMARY OF CONTRACTS RECOVERING FROM EARLY COST OVERRUNS

Contract Code	Svc	K Type	Final BAC ($M)	Most Unfavorable CV% w/	(PC)	Final CV%
37.4	A	FP	837	-5.8	(29)	5.2
22.13	A	FP	110	-34.4	(29)	3.1
22.14	A	FP	26	-16.7	(23)	3.8
32.9	N	CP	100	-31.5	(73)	1.0
43.1	N	FP	212	-8.7	(22)	1.0
19.3	AF	CP	232	-13.3	(42)	1.0
14.5	AF	FP	749	-5.3	(66)	2.0
15.9	A	FP	33	-7.1	(42)	0.0
Average:			287.4	-15.4		2.1

Svc = DoD Component
A = Army
N = Navy
AF = Air Force
BAC = Budget at Completion
CV% = Cost Variance Percentage
PC = Percent Complete

K Type = Contract Type
FP = Fixed Price Contract
CP = Cost Plus Contract

Of the eight successful contracts, four are Army contracts while there are two contracts from both the Air Force and the Navy. The majority of contracts have a fixed price arrangement. The average final BAC for the eight successful contracts is $287.4M and the average final cost variance is 2.14%. Maximum unfavorable cost variances on the eight contracts ranged from -5.3% to -34.4%. Maximum unfavorable cost variance percentages on these eight contracts were encountered as early as the 22 and as late as the 73 percent complete points.

The cost performance of the eight successful contracts was compared against the cost performance of the remaining 295 contracts in the sample to determine if statistically significant differences existed. Specifically, the average cost variance percentage of the two groups was compared at the 25, 50, 75, and 100 percent complete points using a two-sample t-test.

The Rankit plots and Wilk-Shapiro statistic for the 25, 50, 75, and 100 percent complete points are provided in Figures 2, 3, 4, and 5.

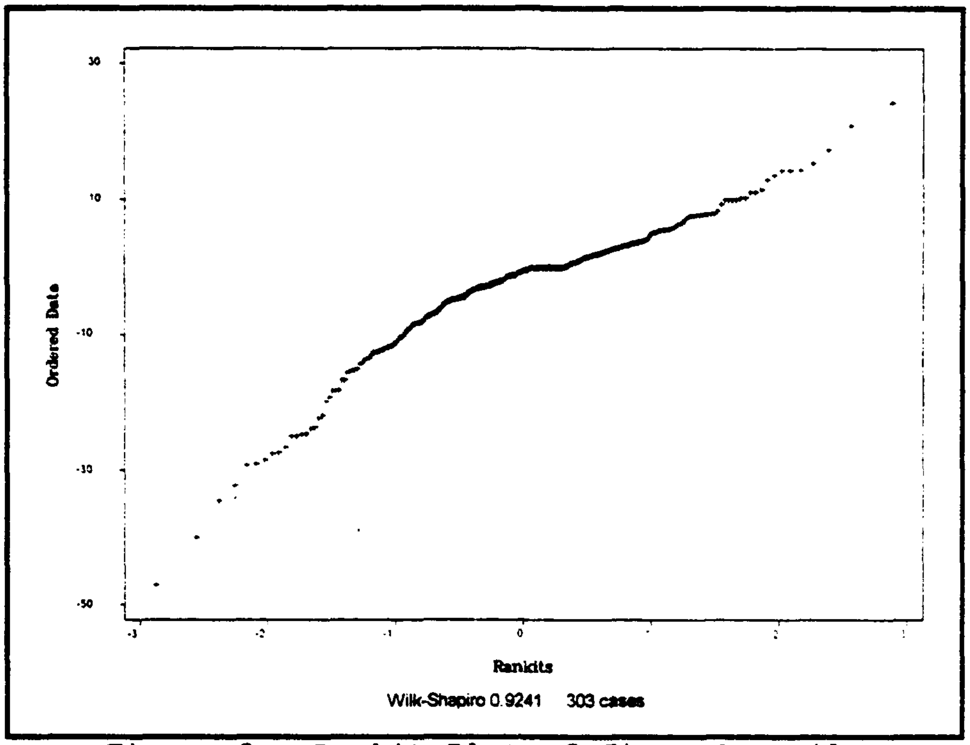

Figure 2. Rankit Plot of First Quartile Cost Variance Percentage

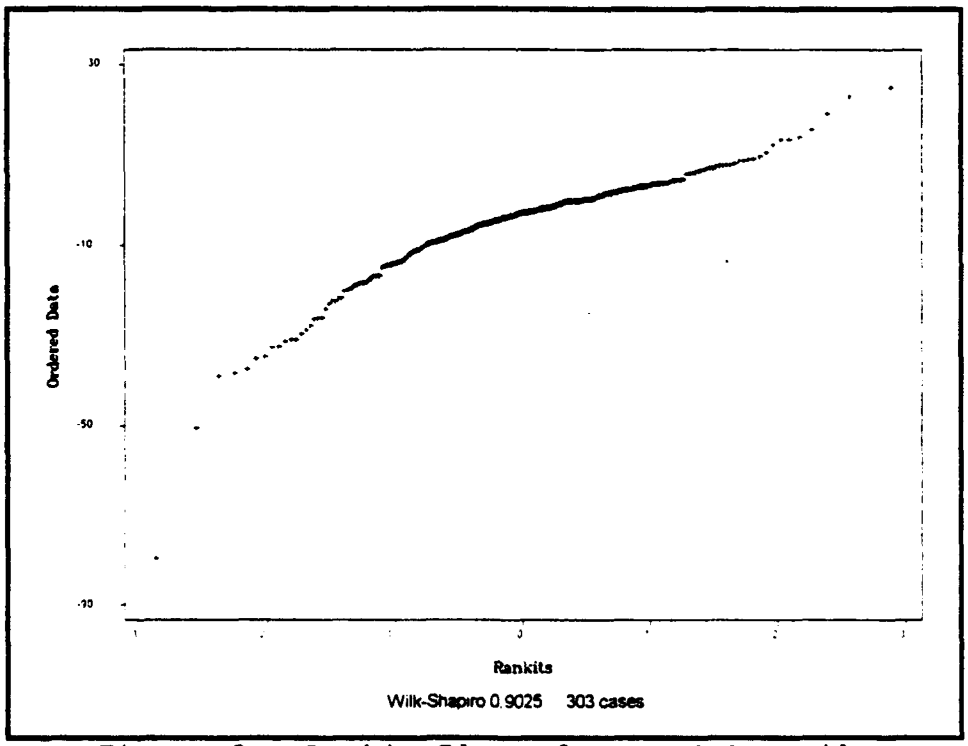

Figure 3. Rankit Plot of Second Quartile Cost Variance Percentage

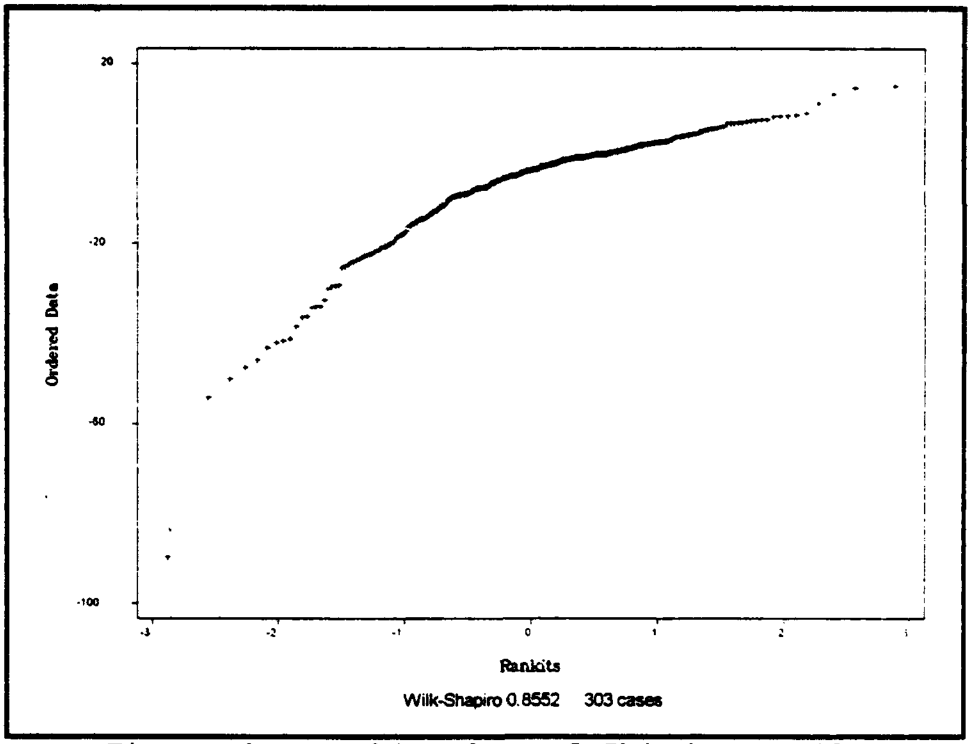

Figure 4. Rankit Plot of Third Quartile Cost Variance Percentage

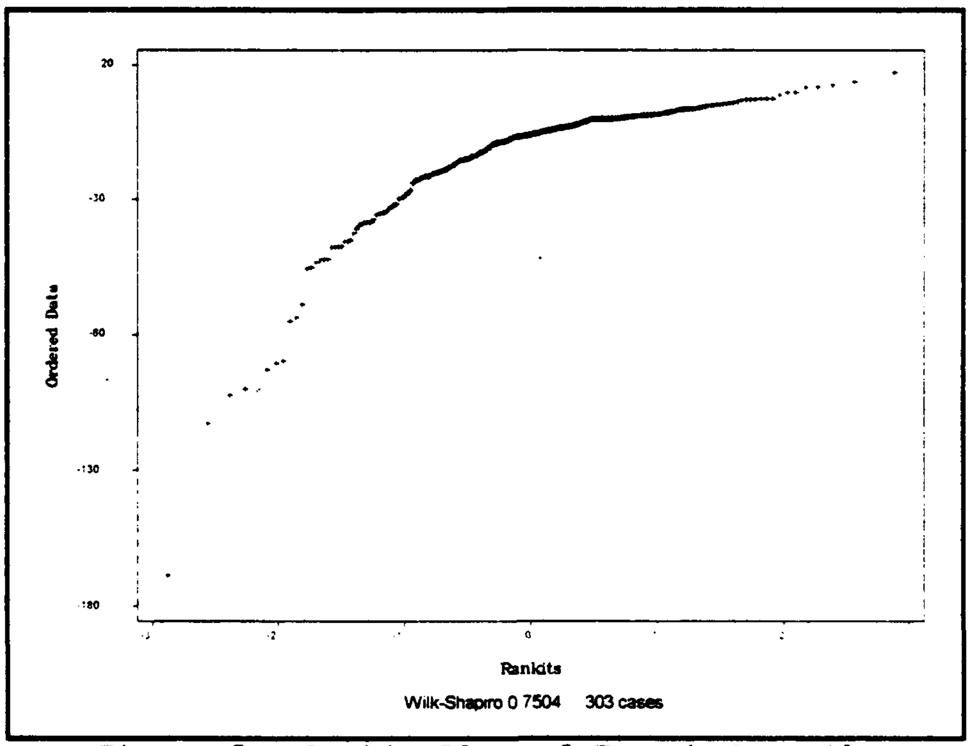

Figure 5. Rankit Plot of Fourth Quartile Cost Variance Percentage

The Wilk-Shapiro statistic provides a quantitative measure of the normality of the sample. The Wilk-Shapiro statistics for each quartile, along with the associated p-values, are presented in Table 2.

TABLE 2

WILK-SHAPIRO STATISTIC FOR
MEAN COST VARIANCE PERCENTAGE BY QUARTILE

Quartile	Wilk-Shapiro	p-value
First	0.9241	0.0001
Second	0.9025	0.0001
Third	0.8552	0.0001
Fourth	0.7504	0.0001

The Rankit plots and Wilk-Shapiro statistics indicated the samples were not perfectly normally distributed. The Wilk-Shapiro statistics suggested the data were non-normal. However, several outliers, which are known to heavily influence the Wilk-Shapiro statistic, were evident in the Rankit plots (16). Despite the low Wilk-Shapiro statistics, the data appeared relatively normal in the Rankit plots.

Since the data appeared approximately normal, use of the two-sample t test was appropriate. Results of the comparisons from the two-sample t tests are summarized in Table 3.

TABLE 3

COMPARISON OF MEAN COST VARIANCE PERCENTAGE
FOR "SUCCESSFUL" CONTRACTS AND REMAINDER OF DATABASE

PC	Mean CV_R%	Std Dev	Mean CV_S%	Std Dev	t_{calc}	Pooled s.e.	p-value
25%	-7.72	8.91	-2.55	9.57	1.62	9.56	0.1472
50%	-5.39	3.00	-4.95	11.39	0.35	11.26	0.7308
75%	-2.89	7.76	-6.94	12.61	1.43	12.52	0.1908
100%	2.15	1.75	-13.13	22.57	10.52	22.30	0.0000

PC = Percent Complete
CV_R% = Cost Variance Percentage for "Successful" Contracts
CV_S% = Cost Variance Percentage for Remainder of Database

With $\alpha = .05$, the differences between the means at the 25, 50, and 75 percent complete points are statistically insignificant. At contract completion, the difference between the means was statistically significant ($p < 0.0001$). The eight contracts that recovered from cost overruns performed significantly better in the final quarter of the contract than the rest of the sample.

A plot of the comparison of the mean cost variance percentages ($\overline{CV\%}$) as the contracts progressed through the 25, 50, 75, and 100 percent complete points illustrates the opposite directions the CV%s were heading as the contracts moved toward completion. This plot is shown in Figure 6.

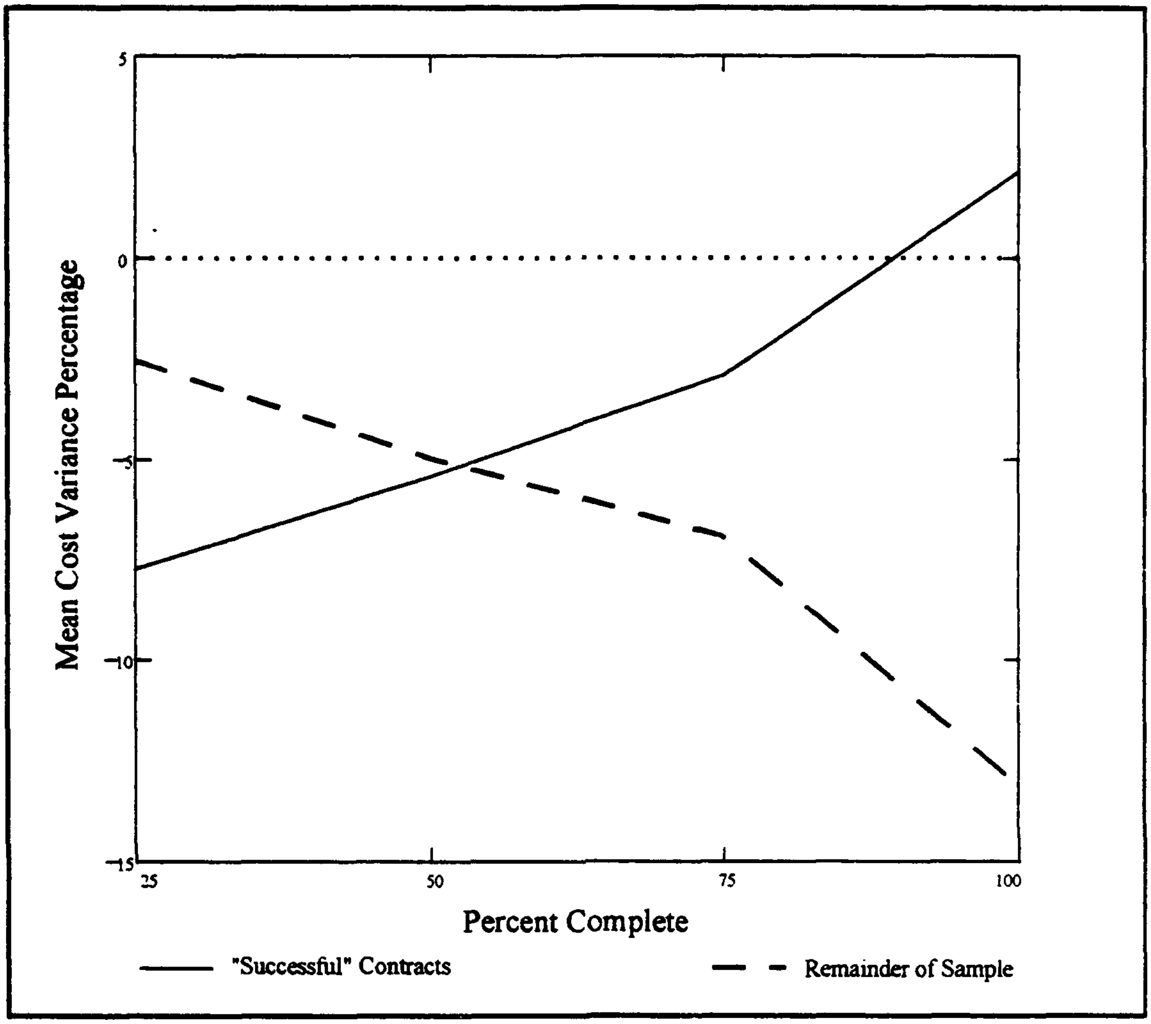

Figure 6. Mean Cost Variance Percentage Comparison of "Successful" Contracts vs. Remainder of Sample by Quartile

Figure 6 depicts the favorable trend experienced by the "successful" contracts as compared to the adverse trend experienced by the remainder of the contracts in the sample. More specifically, the "successful" contracts experienced a more unfavorable cost variance percentage early in the contract life (-7.72% at 25 percent complete) than the remainder of the contracts in the sample (-2.55% at 25 percent complete). However, the "successful" contracts recovered to a favorable cost variance percentage (2.15% at 100 percent complete) while the remaining contracts' cost variance percentages steadily declined (-13.13% at 100 percent complete).

As a means of determining the cause of the recoveries, the stability of the Performance Measurement Baseline (PMB), exhibited by changes in BAC, for the eight contracts was compared to that of the entire sample. The results of this comparison are detailed in Table 4.

TABLE 4

SUMMARY OF BAC CHANGES FOR CONTRACTS
RECOVERING FROM EARLY COST OVERRUNS

Contract Code	Initial BAC ($M)	Final BAC ($M)	# BAC Changes	% BAC Change	% BAC Change due to MR
37.4	831	837	6	2.41	0.60
22.13	83	110	7	37.35	12.05
22.14	25	26	2	12.00	12.00
32.9	64	100	8	65.63	6.25
43.1	182	212	12	19.78	10.99
19.3	278	232	9	37.41	19.42
14.5	638	749	9	17.71	0.78
15.9	30	33	2	10.00	6.67
Mean % BAC Change for Sample:				67.39	11.39

BAC = Budget at Completion
MR = Management Reserve

The average change in BAC for the eight contracts is 25.29%, as compared to 67.39% for the entire sample, indicating a significant difference in PMB stability between successful contracts and the rest of the sample.

The average change in BAC due to the use of Management Reserve (MR) for the successful contracts is 8.60%, as compared to 11.39% for the entire sample. This indicates no significant difference between the two groups. Therefore, the greater stability of the PMB seen in contracts recovering from cost overruns is not due to differences in the use of MR.

In further investigating the causes of recovery, an in-depth study of Contract 37.4 was conducted. Review of the supplementary forms to the Cost Performance Reports revealed recovery was due primarily to correction of accounting errors, changes in material prices, and correction of misclassified spares cost.

In one case the supplementary form showed a $1.7M favorable cost variance due to changes in the price materials. Another report showed a $2.9M favorable cost variance was due primarily to recovery of earned value for spares paid for in a prior month. Several reports identified a favorable variance resulting from application of rates and factors. The largest favorable cost variance ($21.5M) was due to removal of credits for spares from the Major End Items category, where they had been erroneously placed. There was no indication recovery resulted from proactive management efforts.

The analysis of the eight contracts recovering from early cost overruns indicates similar performance to the remainder of the sample through the 75 percent complete point with much higher performance in the latter part of the contracts. These successful contracts exhibited a more stable PMB. However, detailed analysis of one successful contract failed to reveal any specific action taken by the contractor which led to the recovery.

Analysis of Contractor Performance

In an effort to determine if a statistically significant difference exists between contractors, One-Way Analysis of Variance (ANOVA) was employed. One-Way ANOVA was used to compare the mean cost variance percentages ($\overline{CV\%}$) of all contractors in the sample at the 25, 50, 75, and 100 percent complete points (first, second, third, and fourth quartiles). The $\overline{CV\%}$ at each quartile for all contractors is presented in Table 5.

TABLE 5

SUMMARY OF CONTRACTOR COST VARIANCE PERCENTAGE BY QUARTILE

Ktr Code	Mean CV% (by Quartile) First	Second	Third	Fourth	# of Ks
1	3.85	-0.33	-3.10	-7.25	4
2	-2.70	-2.37	-2.53	-6.00	3
3	-0.28	-0.85	-4.00	-4.25	4
4	8.10	4.85	5.35	8.00	2
5	-6.74	-6.52	-7.82	-19.60	5
6	-0.05	-0.58	-1.07	-2.86	22
7	2.40	-1.40	-1.30	0.00	1
8	-18.20	-17.40	-15.20	-21.00	1
9	3.40	3.80	1.60	0.00	1
10	-1.13	-5.58	-4.05	-25.50	4
11	1.58	-5.88	-4.27	-10.00	4
12	-5.42	-13.18	-15.80	-29.00	5
13	1.40	-5.40	-14.30	-18.00	1
14	-3.85	-6.83	-6.34	-14.94	33
15	1.26	0.86	-2.28	-7.17	23
16	-2.10	-1.90	-0.20	3.50	2
17	-16.70	-18.30	-22.20	-17.00	1
18	-7.63	-8.38	-9.35	-6.67	6
19	-2.80	-1.78	-1.96	-6.00	5
20	5.96	4.76	3.54	2.80	5
21	0.00	-3.75	0.00	-5.00	2
22	-9.71	-13.38	-15.55	-25.20	15
23	0.94	-5.36	-7.14	-14.40	5
24	0.83	-1.02	-2.42	-23.83	6
25	-19.30	-18.40	-7.20	-7.00	1
26	-2.90	-2.40	-7.45	-22.50	2
27	1.45	-0.85	-1.75	-0.50	2
28	-4.09	-2.63	-3.88	-4.63	8
29	-1.13	-1.46	-6.47	-13.71	7
30	-11.80	-30.70	-12.20	-35.00	1
31	2.36	-3.16	-8.01	-17.13	16
32	-6.31	-11.14	-18.05	-21.15	13
33	6.00	1.30	-0.45	-2.00	4
34	-8.05	-12.65	-14.05	-20.00	2
35	-10.20	-18.60	-24.10	-27.00	1
36	-2.86	-3.56	-9.73	-14.88	8
37	-1.13	-0.29	-4.00	-8.60	20
38	-0.02	-3.99	-5.11	-7.50	16

TABLE 5 (con't)

SUMMARY OF CONTRACTOR COST VARIANCE PERCENTAGE BY QUARTILE

Ktr Code	Mean CV% (by Quartile) First	Second	Third	Fourth	# of Ks
39	0.00	-13.90	-2.80	-20.00	1
40	0.00	0.00	0.00	0.00	1
41	-3.56	-6.36	-3.96	-0.60	5
42	-27.00	-15.90	-0.75	-131.00	2
43	-4.53	-10.13	-12.51	-9.29	7
44	-14.50	-8.25	-2.20	-2.00	2
45	-4.70	-3.60	-2.60	-3.00	1
46	-10.38	-13.27	-17.70	-20.50	14
47	-1.30	-2.00	-2.40	-5.00	1
48	-3.90	-6.43	-12.67	-12.57	7
49	-2.20	0.40	2.60	1.00	1
Average	-2.69	-4.96	-6.84	-12.73	
Total					303

CV% = Cost Variance Percentage
Ktr = Contractor
K = Contract

Since One-Way ANOVA requires equality of variances, Bartlett's Test for equality of variances was conducted. Contractor #21 had only two contracts, both of which had the same CV% at the 25 and 75 percent complete points. This caused Contractor #21 to have a CV% variance of zero at the first and third quartiles. Bartlett's Test cannot be conducted if any group variance is near zero. Therefore, the equality of variance test was conducted without Contractor #21 at the first and third quartiles. The results of Bartlett's test are presented in Table 6.

TABLE 6

BARTLETT'S TEST FOR EQUALITY OF VARIANCE
BETWEEN CONTRACTORS

Quartile	Bartlett's Statistic	p-value
First	57.55	0.0070
Second	94.69	0.0000
Third	93.09	0.0000
Fourth	130.42	0.0000

The p-values provided by Bartlett's Test indicate the variances between groups are not equal. However, One-Way ANOVA is only slightly affected by unequal variances (15:624). Therefore, One-Way ANOVA was still the preferred test for comparison of mean cost variance percentages.

The second requirement to use the fixed effects ANOVA model is normality of the data. The data used for comparison of mean cost variance percentages between contractors is the same data evaluated in the first part of the thesis, "Contract Recoveries". Therefore, the Rankit plots and Wilk-Shapiro statistics presented previously (Figures 2, 3, 4, 5 and Table 2) were used to analyze the data for comparison between contractors.

Although the Wilk-Shapiro statistics indicate the data are non-normal, the Rankit plots show the data to be relatively normal. Additionally, the fixed effects ANOVA model is robust against small departures from normality. Therefore, One-Way ANOVA was determined to be the best method for comparison of mean cost variance percentages between contractors. The results of the One-Way ANOVA test for comparison of mean cost variance percentages of the 49 contractors at each quartile of contract completion are presented in Table 7.

TABLE 7

COMPARISON OF CONTRACTORS' MEAN COST VARIANCE PERCENTAGES

Quartile	F_{calc}	p-value
First	1.81	0.0020
Second	1.47	0.0312
Third	1.39	0.0575
Fourth	2.40	0.0000

With α = .05, One-Way ANOVA indicates there are significant statistical differences between contractors at the 25, 50, and 100 percent complete points. With a p-value of 0.0575, there are no statistical differences between contractor cost variance percentages at the 75 percent complete point.

To further investigate the differences in the first, second, and fourth quartiles, a pairwise comparison of means was conducted using Statistix Analytical Software (19). The pairwise comparison of means identified certain contractors which were primarily responsible for the small p-values. The One-Way ANOVA test was run again without the outlying contractors. The results of the ANOVA test are presented in Table 8.

TABLE 8

COMPARISON OF CONTRACTORS' MEAN COST VARIANCE PERCENTAGES WITHOUT OUTLYING CONTRACTORS

Quartile	Ktr Removed	F_{calc}	p-value
First	#42	1.53	0.0211
Second	#30	1.38	0.0606
Fourth	#42	1.01	0.4563

Ktr = Contractor

As Table 8 illustrates, removal of a single contractor at each quartile results in a significant increase in the respective p-value. In the case of the second and fourth quartiles, removal of a single contractor led to acceptance of the null hypothesis; no significant statistical difference exists between contractors.

In addition to the comparison of mean cost variance percentage, the mean, most unfavorable schedule variance percentage ($\overline{SV_u\%}$) was compared across contractors. Since

One-Way ANOVA was used to compare $\overline{SV_u\%}$, equality of the variances and normality of the data had to be tested.

As with the comparison of mean cost variance percentages, equality of variance between contractors' $\overline{SV_u\%}$s was tested using Bartlett's test. Since Contractor #21 had only two contracts with equal schedule variance percentages, Bartlett's test was computed without Contractor #21. Bartlett's test provided a test statistic of 80.88 (p-value = 0.0000). However, One-Way ANOVA is only slightly affected by unequal variances. Therefore, One-Way ANOVA was deemed appropriate for the comparison of contractors' $\overline{SV_u\%}$.

The test for normality was accomplished with a Rankit plot and the Wilk-Shapiro statistic. The results of the normality tests are provided in Figure 7.

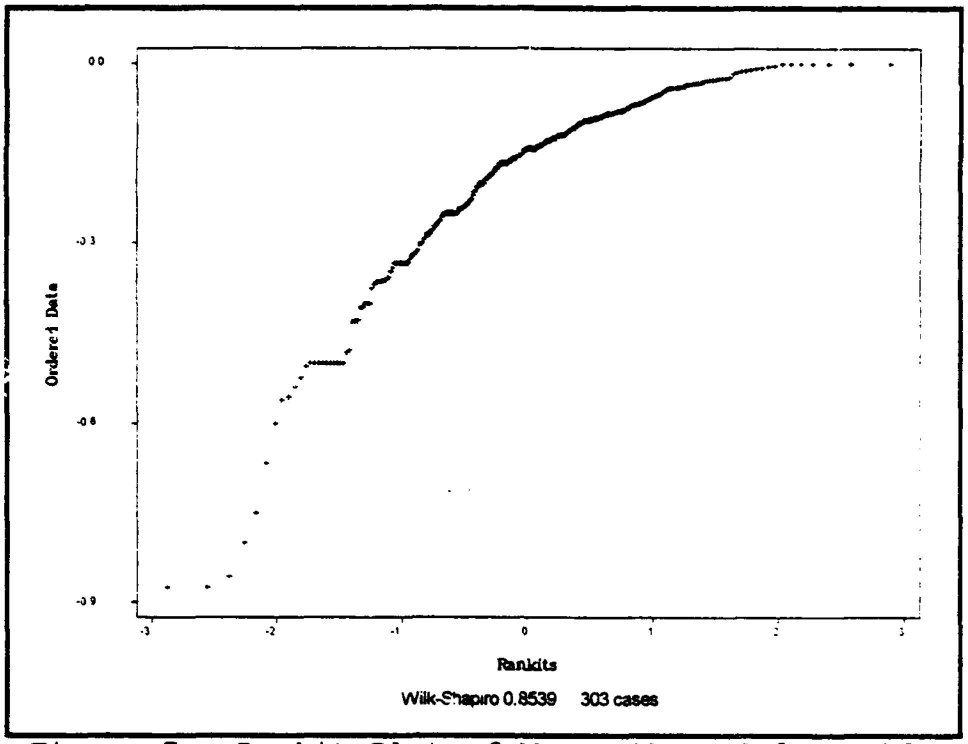

Figure 7. Rankit Plot of Mean, Most Unfavorable Schedule Variance Percentage

The associated p-value for the mean, most unfavorable schedule variance percentage is 0.0001. The Wilk-Shapiro statistic indicates the data are non-normal. However, the Rankit plot illustrates the data are relatively normal, ignoring the apparent outliers. The apparent outliers also have a significant effect on the Wilk-Shapiro statistic. The fixed effects ANOVA model is robust against small departures from normality.

The initial ANOVA results indicate a significant statistical difference between contractors' mean, most unfavorable schedule variance percentage. However, a pairwise comparison of means, using Bonferroni's method, indicated Contractors #22 and #46 were primarily responsible for the difference in contractor $\overline{SV_u\%}$. Therefore, One-Way ANOVA was computed a second time without the aforementioned contractors. The ANOVA results, with and without Contractors #22 and #46, are presented in Table 9.

TABLE 9

COMPARISON OF CONTRACTORS' MEAN, MOST UNFAVORABLE SCHEDULE VARIANCE PERCENTAGES

Ktrs Included	F_{calc}	p-value
All	1.75	0.0032
Minus #22,#46	1.30	0.1084

Ktr = Contractor

As Table 9 illustrates, a significant statistical difference exists when all contractors were compared. However, removal of Contractors #22 and #46 resulted in no significant statistical difference among the contractors.

This concludes the presentation of the analysis. The next chapter presents the conclusions of the thesis project as well as areas for further study.

V. Conclusions and Recommendations

Contract Recoveries

The analysis of the 303 contracts indicated that recovery from early cost overruns is a rare occurrence. Additionally, determining the cause of the recoveries did not prove to be a simple task. The "successful" contracts covered a wide range of contract scenarios and an in-depth analysis of a single "successful" contract revealed little information as to the management actions which might lead to a recovery.

Statistical testing indicated a significant statistical difference did exist between the "successful" contracts and the remainder of the contracts in the sample. The cost variance percentage on "successful" contracts steadily improved, while the cost variance percentage on the remainder of the contracts in the sample steadily declined.

The single concrete measure which indicated a possible cause for recovery on the "successful" contracts was the stability of the performance measurement baseline (PMB). The "successful" contracts experienced a significantly more stable PMB than the remaining contracts. A stable PMB permits more accurate planning and leads to more effective use of resources.

The actions which lead to recovery from cost overruns are yet unknown. Contractors recovering from cost overruns are not following a "get well" management plan. Publication of management actions leading to recovery is currently infeasible.

Contractor Performance

The comparison of mean cost variance percentage between the 49 contractors represented in the DAES database indicated no significant difference between contractors. With the exception of one or two contractors, this result indicates past cost performance should not be a significant factor in source selection for a new contract.

The comparison of mean, most unfavorable schedule variance indicated no significant difference existed between contractors. Only two of the 49 contractors in the sample experienced a mean, most unfavorable schedule variance significantly different from the rest of the sample.

Limitations

As discussed earlier, the statistical test used for comparison of means in the "Contract Recoveries" section required normality of the data. Although the sample failed the normality test, it was assumed the data were approximately normal and the two-sample t test was appropriate.

The statistical test used for comparison of means in the "Contractor Performance" section required normality of the data and equal variances between groups. Although both tests were failed, normality and equality of variances was assumed for reasons presented in Chapter Four.

Recommendations for Further Study

This study concluded recoveries from early cost overruns are rare and potentially caused by actions outside of the program manager's control. The identification of specific management action which may lead to recovery from cost overrun is difficult.

This study also concluded no significant difference exists between contractors in terms of cost or schedule performance. However, the study was limited in scope to mean cost variance percentage and mean, most unfavorable schedule variance percentage.

It is recommended that further analysis of contractors recovering from overruns be conducted. In-depth analysis of several "successful" contractors may identify specific actions which led to recovery from early cost overruns. It is also recommended that Data Envelope Analysis be employed in an effort to determine which contractors form the leading edge of the field in terms of cost or schedule performance.

Appendix: Definitions

Actual Cost of Work Performed (ACWP). The cost incurred and recorded in accomplishing the work performed within a given time period (6:11-B-2-1).

Apportioned Effort. Effort that is not readily divisible into work packages, but is related proportionately to measured effort (6:11-B-2-1).

Authorized Work. Effort that has been definitized and is on contract, plus that for which definitized contract costs have not been agreed to, but for which written authorization has been received (6:11-B-2-1).

Budget At Completion. The total Budgeted Cost of Work Scheduled at contract completion (4:11).

Budgeted Cost of Work Performed (BCWP). The sum of the budgets for completed work packages and completed portions of open work packages, plus the applicable portion of the budgets for level-of-effort and apportioned effort (6:11-B-2-1).

Budgeted Cost of Work Scheduled (BCWS). The sum of budgets for all work packages, planning packages, etc., scheduled to be accomplished (including in-process work packages), plus the amount of level-of-effort and apportioned effort scheduled to be accomplished within a given time period (6:11-B-2-1).

Contract Budget Base. The negotiated contract cost plus the estimated cost of authorized unpriced work (6:11-B-2-2).

Cost Account. A management control point at which actual costs may be accumulated and compared to budgeted cost of work performed. A cost account is a natural control point for cost/schedule planning and control since it represents the work assigned to one responsible organizational element on one contract work breakdown structure element (6:11-B-2-2).

Cost Performance Report (CPR). A monthly summary of the cost and schedule progress of a major defense system usually required on all RDT&E contracts with a value of $60 million or more and procurement contracts with a value of $250 million or more (FY90$) (7:20-7).

Cost/Schedule Control Systems Criteria (C/SCSC). A set of 35 criteria used to provide contractor and government program managers with accurate data to monitor execution of their program and to: 1) preclude the imposition of specific costs and schedule management control systems by providing uniform evaluation criteria to ensure contractor cost and schedule management control systems are adequate; 2) provide an adequate basis for responsible decision-making by both contractor management and DoD component personnel; and 3) bring to the attention of DoD contractors, and encourage them to accept and install, management control systems and procedures that are most effective in meeting requirements and controlling contract performance (6:11-B-1).

Cost/Schedule Status Report (C/SSR). A condensed version of the CPR required for contracts over 12 months in duration and judged not significant enough for C/SCSC application. Contracts less than $5 million (FY90$) are normally excluded (7:20-8).

Cost Variance (CV). The difference between the Budgeted Cost of Work Performed and the Actual Cost of Work Performed (4:20).

Cost Variance Percentage (CV%). The Cost Variance expressed as a percent of BCWP.

Estimate at Completion (EAC). Actual direct costs, plus indirect costs allocable to the contract, plus the estimate of costs (direct and indirect) for authorized work remaining (5:11-B-2-2).

Level-of-Effort (LOE). Effort of a general or supportive nature that does not produce definite end products (6:11-B-2-2).

Management Reserve (MR). An amount of the total allocated budget withheld for management control purposes, rather than designated for the accomplishment of a specific task or set of tasks. It is not part of the performance measurement baseline (6:11-B-2-2).

Over Target Baseline (OTB). An increase resulting in a Total Allocated Budget in excess of the Contract Budget Base (5:11-B-2).

Performance Measurement Baseline (PMB). The time-phased budget plan against which contract performance is measured. It is formed by the budgets assigned to scheduled cost accounts and the applicable indirect budgets. For future effort, not planned to the cost account level, the performance measurement baseline also includes budgets assigned to higher level contract work breakdown structure elements and undistributed budgets. It equals the total allocated budget less management reserve (6:11-B-2-3).

Schedule Variance (SV). The difference between the Budgeted Cost of Work Performed and the Budgeted Cost of Work Scheduled (4:20).

Schedule Variance Percentage (SV%). The Schedule Variance expressed as a percent of BCWS.

Total Allocated Budget. The sum of all budgets allocated to the contract. Total allocated budget consists of the performance measurement baseline and all management reserve. The total allocated budget will reconcile directly to the contract budget base. Any difference will be documented as to quantity and cause.(6:11-B-2-3)

Undistributed Budget. Budget applicable to contract effort which has not yet been identified to contract work breakdown structure elements at, or below, the lowest level of reporting to the Government (6:11-B-2-3).

Work Breakdown Structure (WBS). A product-oriented family tree division of hardware, software, services, and other work tasks which organizes, defines, and graphically displays the product to be produced as well as the work to be accomplished to achieve the specified product (6:6-B-1).

Work Packages. Detailed tasks or material items identified by the contractor for accomplishing work required to complete the contract (6:11-B-2-4).

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Vita

Captain John M. Pletcher was born on 3 February 1966 in Grand Rapids, Minnesota. In 1984, he graduated from Grand Rapids Senior High School. In August of 1988, he graduated from the University of Minnesota-Duluth with a Bachelor of Science Degree in Applied Mathematics. In September of 1989, he graduated as distinguished graduate from the Accounting and Finance Officer Course at Sheppard Air Force Base, Texas. He was then assigned to Lackland Air Force Base, Texas where he served as a Deputy Accounting and Finance Officer. In July 1990, he was reassigned to Reese Air Force Base, Texas where he served as the Accounting and Finance Officer and subsequently as the Financial Services Officer. In May 1993, he entered the Graduate Cost Analysis Program, School of Logistics and Acquisition Management, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio. His follow-on assignment is to Wright Laboratories, Wright-Patterson Air Force Base, Ohio. He is married to the former Karen Anderson from Mendota Heights, Minnesota. They have a daughter named Lauren.

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13. ABSTRACT *(Maximum 200 words)*

This study examines the cause of cost overrun recoveries within Department of Defense (DoD) contracts. In this time of extremely limited congressional funding, it is crucial the DoD avoid cost overruns. Information provided to contracting officers and contractors which would help avoid cost overruns would prove extremely valuable to the DoD. This study attempts to address this problem in two ways: 1) Determine the cause of overrun recoveries; 2) determine whether a statistical difference in cost and schedule performance exists among DoD contractors. Interviews, document reviews, and a two-sample t-test were used to analyze the contracts that recovered from early cost overruns. One-Way Analysis of Variance, along with normality tests and equality-of-variance tests were used to analyze the contractors' cost and schedule performance. The specific contract reviewed for contract recovery actions revealed no specific management action that led to the recovery. Additionally, more than 300 contracts across 49 contractors revealed no significant statistical difference between contractors in the areas of cost and schedule performance.

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